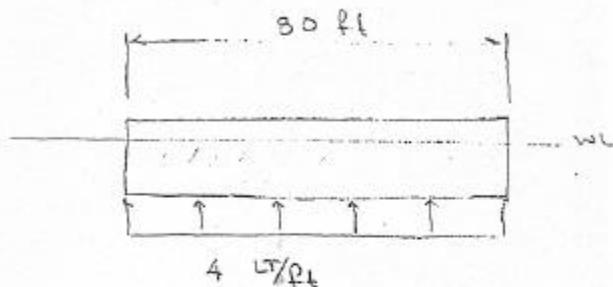


80 ft long, box-shaped barge has uniformly distributed buoyant force of 4 lb/ft^2 .

Find: Resultant buoyant force

Assuming barge is in static equilibrium, what is Δ



Resultant F_B :

$$F_B = (4 \text{ lb/ft}^2)(80 \text{ ft})$$

$$\therefore F_B = 320 \text{ lb} \quad F_B \text{ acts at center of buoyancy, } B$$

*

At static equilibrium, $\Delta = F_B$

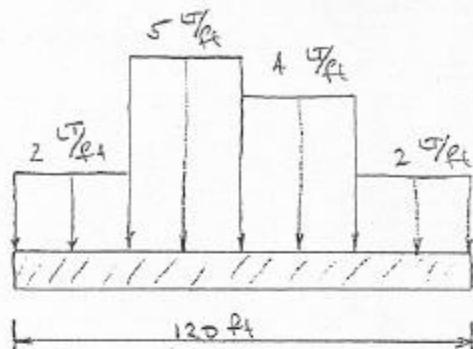
$$\boxed{\Delta_s = F_B = 320 \text{ lb}}$$

* (b) F_B acts at center of buoyancy, B

For a rectangular, box-shaped barge, B located on ℓ , at $\frac{w}{2}$.

B located 40 ft aft of FP

Box-shaped barge has weight distribution shown. Barge is 120 ft long.



a) calculate barge's displacement

distributed loads equally spaced over 30 ft increments

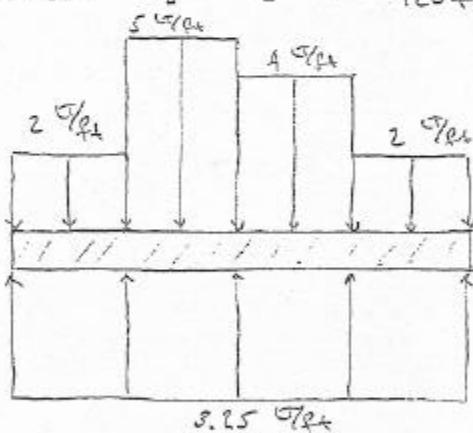
$$\Delta = (30 \text{ ft})(2 \text{ t/ft}) + (30 \text{ ft})(5 \text{ t/ft}) + (30 \text{ ft})(4 \text{ t/ft}) + (30 \text{ ft})(2 \text{ t/ft})$$

$$\boxed{\Delta = 390 \text{ t}}$$

b) uniformly distributed buoyant force.

$$F_B = \Delta = 390 \text{ t}$$

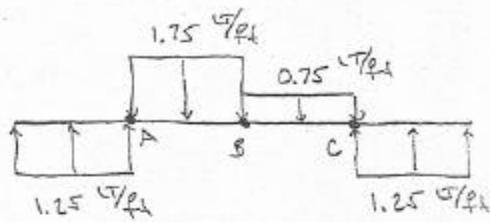
distributed force: $F_B = \frac{F_B}{L} = \frac{390 \text{ t}}{120 \text{ ft}} = 3.25 \text{ t/ft}$



c) why is buoyant force uniformly distributed?

By definition $F_B = \rho g V$. In this case the barge hull is box-shaped, and the barge underwater volume is uniformly distributed along its length. Therefore, buoyant force is uniformly distributed.

d) Draw load diagram.



e) Where will hull experience significant shear stress?

Shear stresses will occur where loads are in opposition, or where there are discontinuities in the load.

On above diagram, points A, B, C will have significant shear

f) longitudinal bending in still water.

SAGGING.

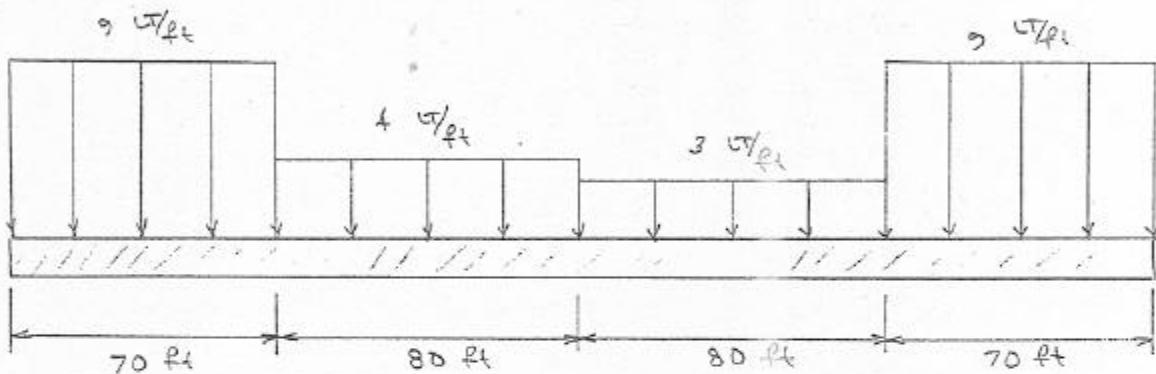
Rectangular, box-shaped barge has following dimensions:

$$L = 300 \text{ ft}$$

$$B = 50 \text{ ft}$$

$$\text{Draft when empty, } T_e = 5 \text{ ft}$$

Empty barge loaded with containers. Containers have following load distribution:



a) Barge's empty displacement

$$\begin{aligned}\Delta_e &= \rho g V_e = \rho g LB T_e \\ &= (64 \frac{\text{lb}}{\text{ft}^3})(300 \text{ ft})(50 \text{ ft})(5 \text{ ft}) (\frac{\text{CT}}{2240 \text{ lb}})\end{aligned}$$

$$\boxed{\Delta_e = 2142.9 \text{ CT}}$$

b) Assuming barge's structure is homogeneous, calculate distributed weight of the empty barge.

homogeneous structure \Rightarrow uniform structure.

$$\text{Distributed weight} = \frac{\Delta_e}{L} = \frac{2142.9 \text{ CT}}{300 \text{ ft}}$$

$$\boxed{\Delta = 7.14 \frac{\text{CT}}{\text{ft}}}$$

c) Barge loaded displacement

$$\Delta_{load} = \Delta_e + w_{cargo}$$

$$w_{cargo} = \sum w_i$$

$$= (9 \text{ kN/ft})(70 \text{ ft}) + (4 \text{ kN})(80 \text{ ft}) + (3 \text{ kN})(80 \text{ ft}) + (5 \text{ kN})(70 \text{ ft})$$

$$w_{cargo} = 1820 \text{ kN}$$

$$\Delta_{load} = 2142.9 \text{ kN} + 1820 \text{ kN}$$

$$\boxed{\Delta_{load} = 3962.9 \text{ kN}}$$

d) Uniformly distributed buoyant force acting on loaded barge

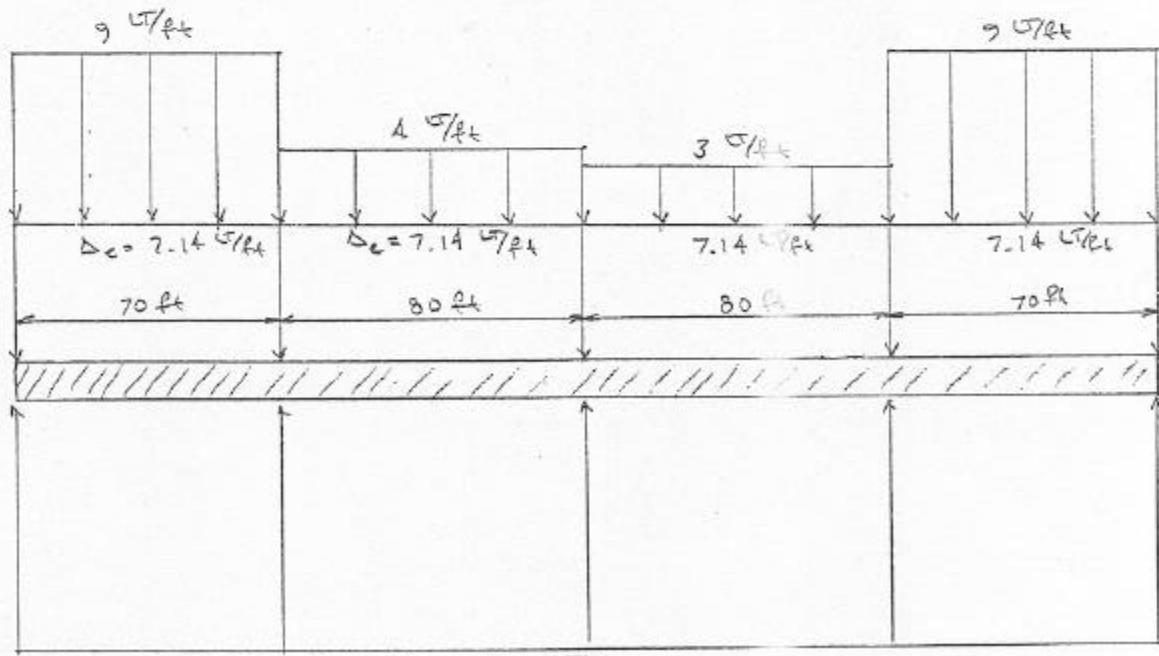
$$F_B = \Delta_{load} = 3962.9 \text{ kN}$$

$$\text{Barge is rectangular box, } \therefore F_B = \frac{3962.9 \text{ kN}}{L} = \frac{3962.9 \text{ kN}}{300 \text{ ft}}$$

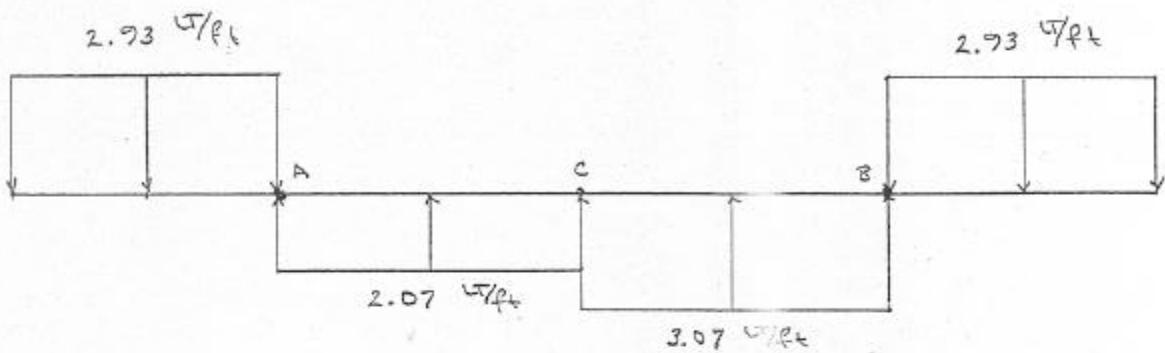
$$\boxed{F_B = 13.21 \text{ kN/ft}}$$

e) Determine load diagram for loaded barge

need to account for distributed weight of empty barge, cargo, and distributed buoyant force.



e) Load diagram: Sum of $w_{cargo} + \Delta_a + F_a$

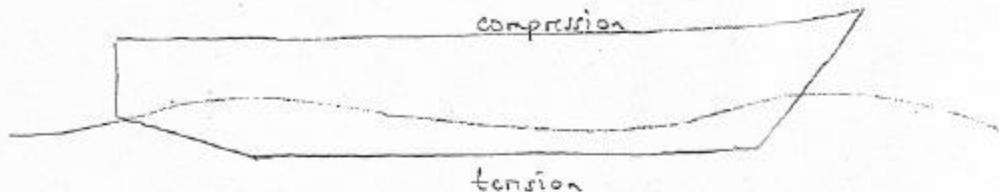


f) In calm water, barge will be HOGGING

g) Barge will experience shear stress where discontinuity of loading occurs.

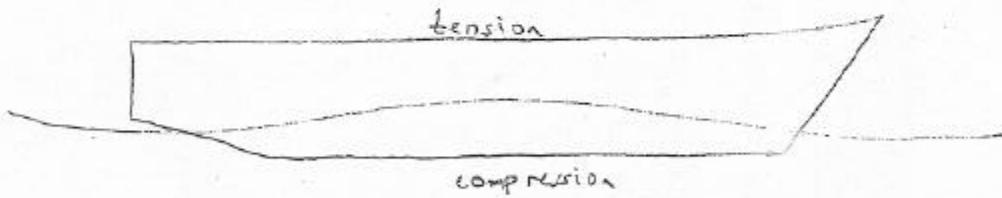
Significant shear will be at Point A & B (on load diagram), with Point C also showing shear.

4. On a profile sketch of a ship, show a wave resulting in sagging, and areas of ship in tension and compression



for sagging: deck in compression, keel in tension

5. On a profile sketch of a ship, show a wave resulting in hogging and the areas of the ship in tension and compression.



for hogging: deck in tension, keel in compression

Box-shaped barges have uniformly distributed buoyant force. Explain why destroyers do not have uniformly distributed buoyant force.

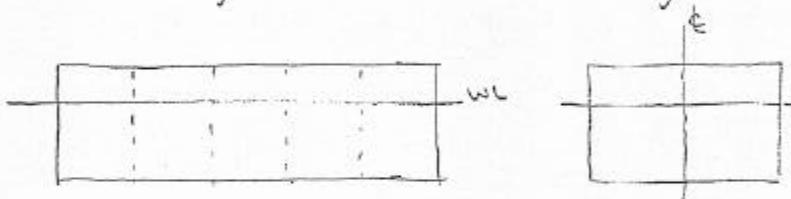
First: definition of buoyant force.

$$F_B = \rho g V$$

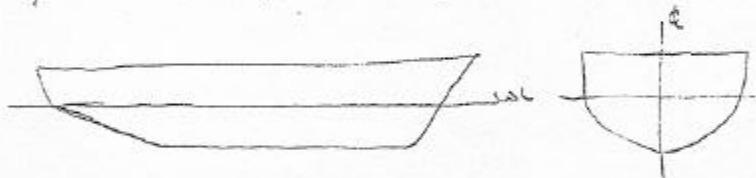
If a hull (any hull) is divided into small segments of volume, the buoyant force can be written as:

$$F_B = \rho g (\sum V_i) ; \text{ where } i \text{ represents each hull segment}$$

A box-shaped barge has constant volume segments as shown below:



A destroyer does not have a constant hull form:

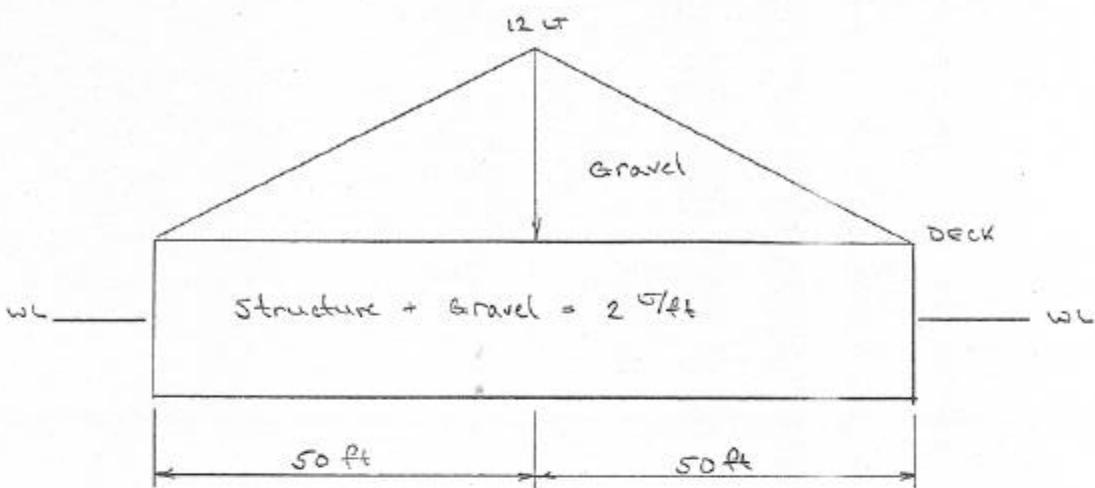


Since hull form changes along its length, the buoyant force of each hull segment changes.

Problems that non-uniform buoyant force presents to designer:

- need to balance hull weight (structure) to buoyant force.
- ship may be in hogging or sagging condition
- need to carefully calculate bending stress along entire hull
- need to vary size of structural elements along ship length.
- bow & stern not supported by buoyant force.

A 100 ft long box-shaped barge loaded with gravel as shown below. interior of the barge loaded uniformly up to the deck.



a) Calculate barge's displacement.

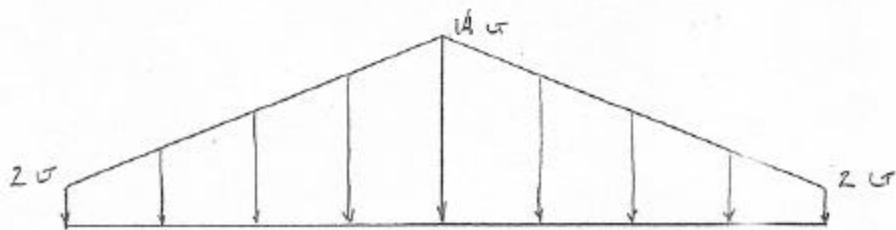
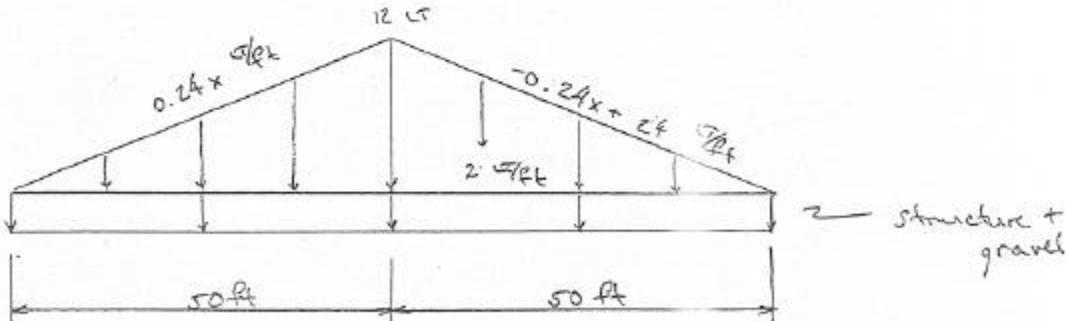
$$\Delta = (\text{weight of structure} + \text{gravel}) + (\text{weight of gravel on deck})$$

$$\Delta = (25 \text{ ft})(100 \text{ ft}) + \frac{1}{2}(12 \text{ ft})(50 \text{ ft}) + \frac{1}{2}(12 \text{ ft})(50 \text{ ft})$$

$$\Delta = 200 \text{ ft} + 300 \text{ ft} + 300 \text{ ft}$$

$$\boxed{\Delta = 800 \text{ ft}}$$

b) Draw diagram showing barge's displacement as a distributed force



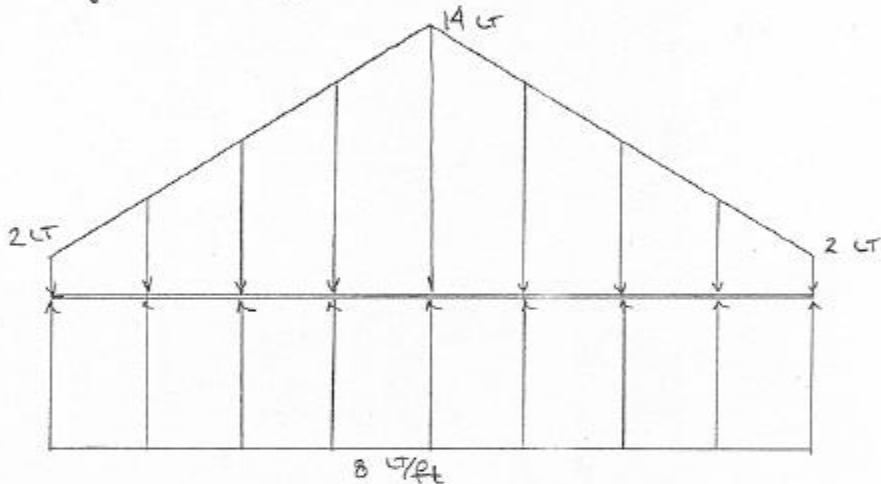
- c) Calculate barge's distributed buoyant force. Is buoyant force uniformly distributed?

Buoyant force will be uniformly distributed. This is because the barge is box-shaped and underwater volume is uniformly distributed along its length.

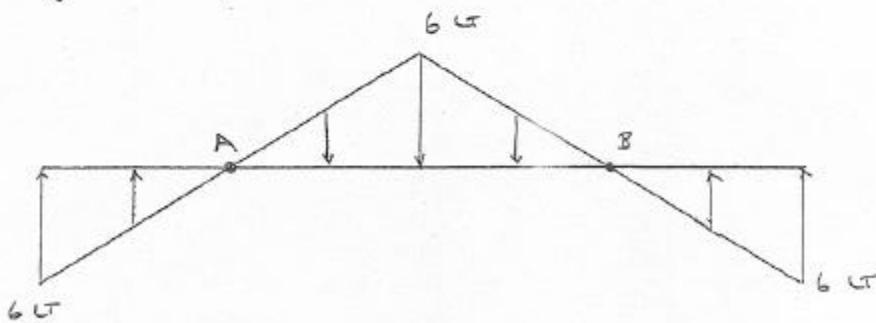
$$F_B = \Delta = 800 \text{ t}$$

$$\text{Distributed force} = \frac{\frac{1}{2} \Delta}{L} = \frac{800 \text{ t}}{100 \text{ ft}} = 8 \text{ t/ft}$$

- d) Calculate and draw the load diagram combined weight + buoyant force.



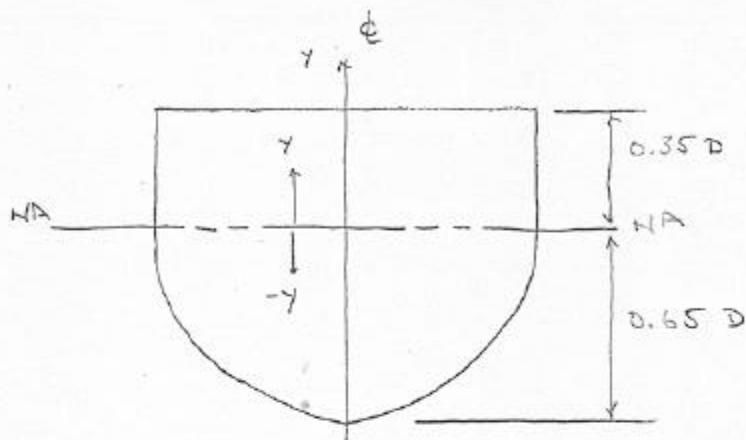
summing weight + buoyant force:



- e) Significant shear stress: points A + B where direction of resultant load change

- f) In calm water barge will be maxima

Sketch a section of a ship where neutral axis is 65% of the depth up from the keel. Use elastic flexure formula to answer following questions:



elastic flexure formula: $\sigma = \frac{My}{I}$

- a) magnitude of bending stress at N.A.

$$\text{at N.A. } y=0, \therefore \sigma = \frac{My}{I} = 0 \text{ lb/in}^2$$

- b) which portion of section will see greatest magnitude of bending stress?

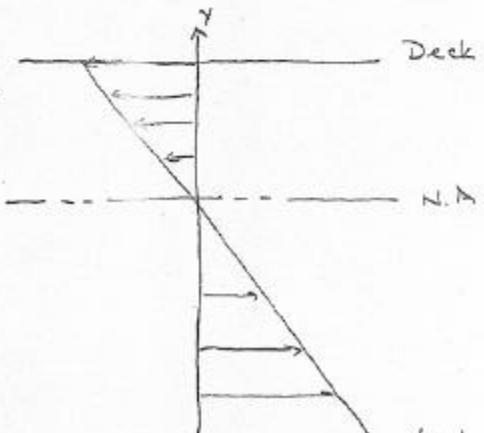
Keel sees greatest stress \rightarrow furthest from N.A.

$$\text{at keel: } \sigma = \frac{M(0.65D)}{I}$$

$$\text{at deck: } \sigma = \frac{M(0.35D)}{I}$$

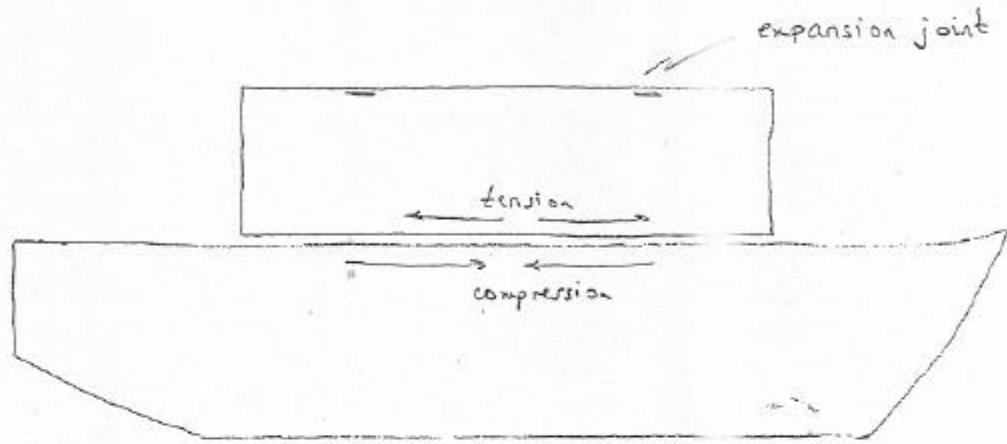
- c). draw diagram of bending stress distribution from keel to deck if ship is sagging.

Sagging: deck in compression
keel in tension



Using an appropriate diagram, show why significant shear stresses develop between hull and superstructure if expansion joints are not used.

13-082 50 SHEETS FELT 5 SQ YARD
42-381 50 SHEETS EVA/EPS 6 SQ YARD
42-382 100 SHEETS PVC 5 SQ YARD
42-383 100 SHEETS PVC 5 SQ YARD
42-387 1000 RECYCLED WHITE 5 SQ YARD
42-390 2000 RECYCLED WHITE 5 SQ YARD
Made in U.S.A.
National Strand



In a sagging condition, the deck will be in compression, however, the bottom of the superstructure will be in tension. These opposing forces create very large shear stresses at the connections.

By installing expansion joints, the superstructure is allowed to flex along with the hull.

10. What is the purpose of transverse elements in a ship's framing system?

Transverse elements resist hydrostatic force.

Ships less than 300 ft in length, and submarines will have more transverse elements than longitudinal elements.

13-782
100 SHEETS FULLER 5 STARLING
42-581 50 SHEETS EVER-SEAL 5 STARLING
42-582 100 SHEETS EVER-SEAL 5 STARLING
42-583 200 SHEETS EVER-SEAL 5 STARLING
42-584 100 RECYCLED WHITE 5 STARLING
42-585 200 RECYCLED WHITE 5 STARLING
Made in U.S.A.

11. What is the purpose of longitudinal elements in a ship's framing system?

Longitudinal elements resist longitudinal bending moments.

Ships greater than 300 ft have more longitudinal elements

12. What type of framing system do most naval ships use?

Navy ships use a combination of longitudinal and transverse framing systems. This system uses the strengths of both longitudinal and transverse framing systems, and gives the ship's structure excellent stiffness and resistance to external loading.

13. If longitudinal bending moments are the major load on ship structures, why are stringers smaller than deck girders or longitudinals? Use elastic flexure formula.

$$\sigma = \frac{My}{I}$$

Stringers are found close to the neutral axis, where bending stress is very small. Since stresses are small, smaller structural members can be used. Less weight!

↳ or, near neutral axis, "y" is small number and therefore a structural member with smaller "I" can be used

14. Magnitude of bending stress in keel is usually the maximum bending stress a ship's section will experience. Since magnitude of bending stress is independent of material properties, why would keel of steel with $\sigma_y = 80,000$ psi be better than keel with $\sigma_y = 60,000$ psi?

$$\sigma = \frac{My}{I}$$

- a. Keel with larger yield stress can absorb a greater amount of bending stress
- b. Keel with $\sigma_y = 80,000$ psi could be constructed out of smaller size structural steel. Smaller components would increase magnitude of bending stress; however, material with increased yield strength would be able to withstand increased stress.

Smaller components = reduced weight, reduced cost

15. When 5" gun fires large recoil forces are exerted on ship's structure. What material properties are desirable for ship's structure to absorb recoil?

Recoil = impact load

Repeated firing (rapid continuous) = cyclic load

Material should have good fatigue resistance, ductile over wide range of temperatures, and structure should be large enough such that stresses do not exceed yield strength.

16. In addition to large bending stresses, flight deck of a carrier is subjected to other large loads.

What types of loading would carrier experience and desirable material properties when selecting a material for the deck.

Loads: impact of aircraft landing
catapult loads
thermal loads from heat and cold

Desirable Properties: ductility over wide temperature range
fatigue resistance - endurance limit
high strength to resist bending stress

17. Watertight bulkheads are an integral part of a ship's structure. In addition to providing stiffness, what other types of loads would watertight bulkhead be subject to?

Hydrostatic forces due to liquids in tanks
Impact load of hull slamming
Thermal expansion / contraction

18. List four common modes of structural failure on a ship.

- tensile or compressive yield failure
- buckling
- fatigue
- brittle fracture

19. What is fatigue of a material? List 4 factors which make a ship susceptible to fatigue failure.

Fatigue is the material's ability to withstand repeated applications of stress.

4 Factors which make a ship susceptible to fatigue:

- type of material
- surface finish
- environment
- geometry
- workmanship

20. Describe effects of material type, temperature, geometry, and rate of loading on brittle fracture.

Material type: High strength, low toughness susceptible to fracture

Temperature:

- As temperature decreases, materials become brittle
- Temperature in welds can cause brittle failure

Geometry:

- Sharp edges and discontinuities cause stress concentrations, and make likely point for crack propagation

Rate of Loading: Impact loads are bad!

21. Why is ductility a desirable property when selecting material for a ship's structure?

Ship at sea will flex with wave loading. Ductile materials will flex, bend, stretch, and compress, and then return to original shape. Ductile materials generally require more energy to fail, both long term and impact energy.

Ship being designed for use in Arctic Ocean. To prevent structural failure, what factors would be taken into account when selecting a material for hull plating.

Environment = harsh! Cold, ice, storms, etc.

- Need a material that remains ductile at very low temp.
 - ∴ low transition temperature.

- Need material that has high impact resistance. Need to resist possible ice impact

- Need good strength characteristics. Able to withstand cyclic stress of waves.

Would material selection criteria change if ship were used exclusively in the Java Sea.

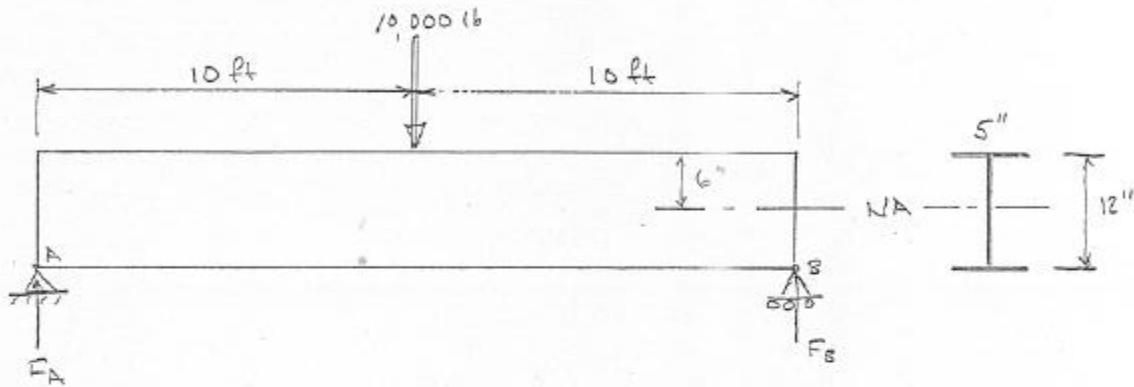
Java Sea is tropical - warm water temperature.

- transition temperature could be higher than material used in Arctic.

- otherwise, still need strength, impact resistance, etc

Simply supported steel I-beam is supporting 10,000 lb load as shown.

Steel: $E = 30 \times 10^6 \text{ psi}$
 $\sigma_y = 50,000 \text{ psi}$
 $\sigma_{ut} = 65,000 \text{ psi}$



- a) vertical reaction forces at each end of beam

$$\sum M_A = 0$$

$$(F_B \cdot 20 \text{ ft}) - (10 \text{ ft})(10,000 \text{ lb}) = 0$$

$$F_B = \frac{(10 \text{ ft})(10,000 \text{ lb})}{20 \text{ ft}} = 5,000 \text{ lb}$$

$$\sum F_y = 0$$

$$F_A + F_B - 10,000 \text{ lb} = 0$$

$$F_A = 10,000 \text{ lb} - F_B = 10,000 \text{ lb} - 5,000 \text{ lb} = 5,000 \text{ lb}$$

$F_A = F_B = 5,000 \text{ lb}$

- b) at current loading condition, $M = 100,000 \text{ ft-lb}$. 2nd moment of beam, $I = 305 \text{ in}^4$. Calculate bending stress at top of beam

$$\sigma = \frac{My}{I} = \frac{(100,000 \text{ ft-lb})(6 \text{ in})(12 \text{ in})}{305 \text{ in}^4 \text{ ft}}$$

$\sigma = 23,600 \text{ lb/in}^2$

Top of beam is in compression.

c) Is design adequate to prevent failure?

$$\sigma = 23,600 \text{ lb/in}^2$$

$$\sigma < \sigma_y \therefore \text{good design}$$

d) Design specs require bending stress to be \leq the yield stress.
Is design adequate?

$$\sigma > \frac{1}{2} \sigma_y \rightarrow 23,600 \text{ lb/in}^2 > \frac{1}{2} (50,000 \text{ psi})$$

To meet design criteria, increase size of beam.

- either make beam taller, i.e. higher than 12 inch, or increase size (I)

e) If beam were constructed of different material, how would this affect magnitude of bending stress?

bending stress is independent of material property.

f) What failure mode will occur if magnitude of bending stress exceeds yield strength?

Yield failure (plastic deformation)

Box shaped oil barge being designed.

$$L = 325 \text{ ft}$$

$$B = 50 \text{ ft}$$

$$D = 15 \text{ ft}$$

$$\text{Empty draft} + T_e = 5 \text{ ft}$$

$$\text{Fully loaded draft} = T_f = 10 \text{ ft}$$

Three materials to build barge:

	Material #1	Material #2	Material #3
$E \text{ (psi)}$	30×10^6	30×10^6	10.4×10^6
$G_y \text{ (psi)}$	47,000	80,000	40,000
$T_{ue} \text{ (psi)}$	71,000	100,000	47,000
endurance limit (psi)	34,000 c infinite	48,000 c infinite	14,000 c 5×10^3 cycle
weight (lb/ft^3)	490	490	175
cost ($\$/\text{lb}$)	7 $\frac{\$/\text{lb}}{16}$	17 $\frac{\$/\text{lb}}{16}$	13 $\frac{\$/\text{lb}}{16}$

a) What is barge's displacement when empty?

$$\Delta_e = \rho g V_e = \rho g L B T_e$$

$$= (64 \frac{\text{lb}}{\text{ft}^3})(325 \text{ ft})(50 \text{ ft})(5 \text{ ft}) \left(\frac{15}{2140}\right)$$

$$\boxed{\Delta_e = 2321.4 \text{ cu ft}}$$

b) Advantages & disadvantages of each material?

Material #1: moderate strength and endurance (A)
low cost (A)

low yield strength, high weight density (D)

Material #2: high strength and endurance (A)

high cost, high weight density (D)

Material #3: low weight density (A)
moderate cost (A)

lowest elastic modulus (D)
lowest yield & ultimate strength (D)

c) what other information desired before making a choice?

what materials are we talking about? (steel, aluminum, gold?)
 what is transition temperature.
 corrosion resistance

d) what material would you select for target structure?

→ Any will work as long as it justified.

choose material & I:

good strength characteristics

good endurance

large difference between yield and ultimate strength

low cost

e) To prevent yield failure, design spec states maximum bending stress must be less than $\frac{1}{2} \sigma_y$.

Current calculations indicate maximum bending stress is 43,000 psi.

How can bending stress be reduced?

$$\sigma = \frac{M y}{I}$$

- increase cross section area of structural members, i.e. increase I.

(increases weight and reduces cargo capacity)

- alter design to reduce bending moment